

## THE SEX RATIO IN *PEROMYSCUS*.

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The data herein presented are based on the records of breeding experiments with *Peromyscus*, conducted by Dr. F. B. Sumner. In an earlier paper<sup>1</sup> the sex ratio in *Peromyscus* was discussed at considerable length and data covering the years 1915-1921 inclusive were presented. The present report is based on the records of births from 1922-1926 inclusive. The material is made up partly of the various mutant strains of the *maniculatus* series, variously hybridized and partly of the three subspecies of *Peromyscus polionotus*, *P. p. polionotus*, *P. p. leucocephalus*, and *P. p. albifrons*, both pure and hybrid. No attempt will be made to give comprehensive interpretation of the findings but reference may be made to the paper cited above for more detailed discussion.

I take this opportunity of acknowledging my indebtedness and sincere thanks to Dr. F. B. Sumner who suggested the subject and under whose general guidance the work was carried out.

The influences which might affect the sex ratio in *Peromyscus* were considered in this treatment of the data to be (1) season, (2) size of litter, (3) race, (4) hybridization.

The total number of broods recorded in the records from 1922 to 1926 is 760, comprising 2,522 young, or an average of 3.32 mice per brood. According to sex these were distributed as follows:

Males .....	1,316
Females .....	1,114
Sex undetermined (dead or escaped) .....	61

The sex ratio (number of males per hundred females) for those of known sex is  $114.93 \pm 3.19$ .<sup>2</sup> It is interesting to note here that the sex ratio for the data from 1915 to 1922 was  $97.37 \pm 1.93$ .

<sup>1</sup> Sumner, McDaniel and Huestis, *BIOL. BULL.*, No. 2, 1922.

<sup>2</sup> The probable error here employed is  $\pm 67.45 (1 + R) \sqrt{\frac{R}{n}}$ , in which  $R$  = sex ratio.

Since the number of individuals considered here is about half as great as that in the previous paper on *Peromyscus*, we shall present the data of this later period only for what they may be worth. At the suggestion of Dr. Sumner it was considered permissible to combine these additional data with the earlier records and thus, in a sense, bring some of the results on the sex ratio of *Peromyscus* up to date.

The total number of broods in the combined data from 1915 to 1926 is 2,321, comprising 7,547 young, or an average of 3.25 mice per brood. According to sex these were distributed as follows:

Males .....	3,597
Females .....	3,492
Sex undetermined (dead or escaped) .....	458

The sex ratio for the combined data is thus  $103.01 \pm 1.64$ .

#### SEASON.

The following table gives the sex ratio for each month of the year and also the number of individuals upon which this ratio is based. The table contains the total data for the years 1922-1926.

January (162) .....	$123.61 \pm 13.29$
February (154) .....	$120.59 \pm 13.21$
March (360) .....	$106.43 \pm 7.64$
April (290) .....	$114.39 \pm 8.94$
May (390) .....	$110.50 \pm 7.65$
June (277) .....	$123.77 \pm 10.12$
July (184) .....	$111.90 \pm 11.30$
August (220) .....	$143.68 \pm 13.50$
September (140) .....	$140.35 \pm 19.42$
October (143) .....	$92.96 \pm 10.67$
November (109) .....	$76.67 \pm 10.15$
December (68) .....	$120.00 \pm 19.30$

As it is obvious from the graph that the differences between the consecutive months are of little significance we may combine our monthly birth records into four seasons of three months each. In both the earlier data alone and in the combined data we may distinguish two high periods and two low periods annually. The sex ratios for these four periods applied to the later data are as follows:

- (1) February–April .....  $111.86 \pm 5.43$
- (2) May–July .....  $114.99 \pm 5.36$
- (3) August–October .....  $126.55 \pm 7.77$
- (4) November–January .....  $105.56 \pm 7.92$

The greatest difference between two of these ratios is that between the third and fourth periods. This difference is  $20.99 \pm 11.09$ .

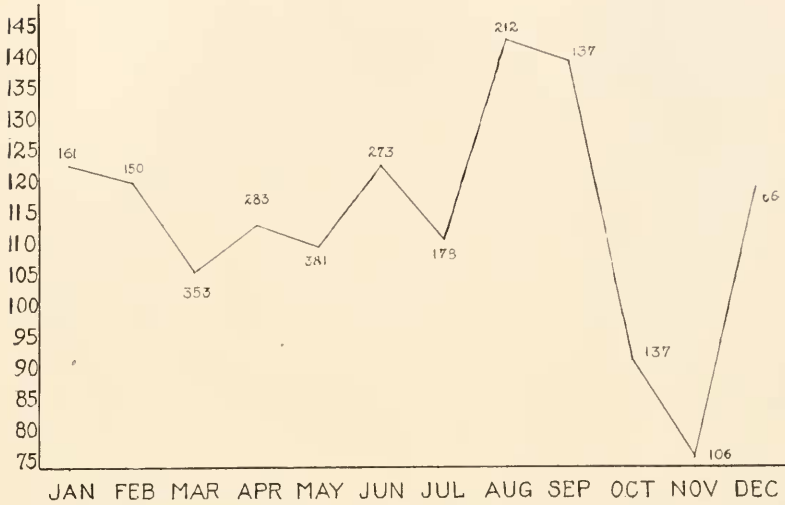


FIG. 1. The sex ratio of *Peromyscus* for each month of the year computed for the data from 1922 to 1926. The figures along the graphs denote the number of individuals born during each month of the year.

Grouping the same data according to the seasons of the year, as employed by King and some others, we get the following sex ratios:

- Spring .....  $110.12 \pm 4.90$   
(March–May)
- Summer .....  $126.28 \pm 6.71$   
(June–August)
- Autumn .....  $102.13 \pm 3.08$   
(September–November)
- Winter .....  $121.76 \pm 8.53$   
(December–February)

Here the greatest difference is between summer and autumn, being in this case  $24.15 \pm 7.38$ . Inasmuch as our figures are small we make no attempt to attach any particular significance

to these values but we may say in passing that they are of the same order of magnitude as the findings of King<sup>1</sup> in the Norway rat. In both we find a maximum in summer followed by a minimum in autumn.

Combining the earlier data (1915-1921) with these additional data we get the following monthly sex ratios:

January (395) .....	103.53 ± 7.41
February (469) .....	99.54 ± 6.17
March (1,129) .....	106.26 ± 4.30
April (660) .....	113.65 ± 6.20
May (967) .....	101.13 ± 4.61
June (707) .....	100.59 ± 5.29
July (592) .....	98.11 ± 5.74
August (818) .....	113.46 ± 5.46
September (617) .....	108.45 ± 6.03
October (564) .....	103.37 ± 6.02
November (367) .....	78.12 ± 5.76
December (279) .....	96.38 ± 7.93

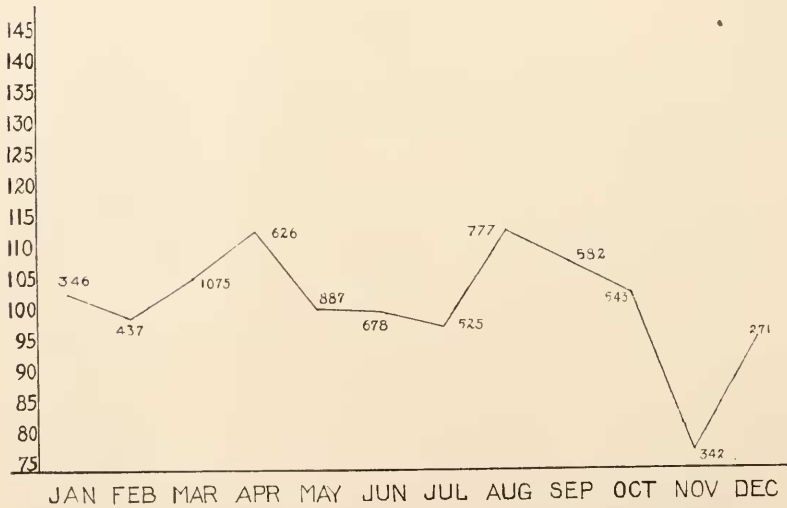


FIG. 2. The sex ratio of *Peromyscus* for each month of the year computed for the combined material from 1915 to 1926. Numbers along graphs indicate numbers born in each month.

Here, as in the earlier data alone, we find two annual maxima, one occurring in March and April; the other from August to Oc-

<sup>1</sup> *Archiv für Entwicklungsmechanik*, 1927, 61.

tober. In the graph we have the appearance of a fairly well marked biennial rhythm.

Now grouping the combined data according to 3-month periods we find the following sex ratios:

(1) February-April .....	106.96 $\pm$ 3.07
(2) May-July .....	100.19 $\pm$ 2.96
(3) August-October .....	107.87 $\pm$ 3.36
(4) November-January .....	91.80 $\pm$ 4.01

The difference between the third and fourth periods is  $16.07 \pm 5.23$  and may be considered of probable significance according to the conventional statistical standard. These figures still show a rather marked biennial rhythm despite the fact that the later data showed reversed relations for the February-April period.

Again, if we regroup the combined data by the ordinarily recognized seasons the figures become:

Spring .....	106.22 $\pm$ 2.78
(March-May)	
Summer .....	104.76 $\pm$ 3.18
(June-August)	
Autumn .....	97.43 $\pm$ 3.45
(September-November)	
Winter .....	100.00 $\pm$ 4.18
(December-February)	

Here the greatest difference, between spring and autumn, is  $8.79 \pm 4.43$  and of no probable significance. Likewise the biennial rhythm, apparent in the case of the later data seems to have been eliminated by the addition of the earlier data. This, we may say, is typical of the conflicting results pervading the entire literature on the sex ratio.

In the previous paper on the sex ratio in *Peromyscus* it was stated that the records were "unfortunately not adapted to revealing definite periods of increased or diminished reproductive activity, since the matings were to a large extent controlled in accordance with the demands of the breeding experiments." Since this statement is equally applicable to the later data, we wish to stress the point that only the number of matings was controlled and we cannot understand how this could possibly affect the normal seasonal trend of the sex ratio<sup>1</sup>

<sup>1</sup> Cf. King, 1927.

## SIZE OF THE BROODS.

The mean size of the 760 broods considered in the later data is 3.32. The following table gives the sex ratios for mice belonging to broods containing from one to seven individuals respectively. Double broods or broods in which individuals of unknown sex are known to have died have been excluded.

No. in Brood.	Males.	Females.	Ratio.
1	17	12	141.67 ± 36.07
2	119	103	115.53 ± 19.44
3	423	336	125.89 ± 6.25
4	352	316	111.39 ± 5.83
5	141	129	109.30 ± 9.02
6	59	31	190.32 ± 28.36
7	18	17	105.88 ± 24.17

Summarizing the combined data we get the following table for the sex ratios according to the size of the brood:

No. in Brood.	Males.	Females.	Ratio.
1	81	73	110.96 ± 12.09
2	351	355	98.87 ± 4.96
3	1,047	993	105.44 ± 3.18
4	1,029	983	104.68 ± 3.18
5	405	385	105.19 ± 4.97
6	159	111	143.24 ± 11.96

Considering either the single or combined data we can find no significant differences in the sex ratios of various sized litters and we can only conclude that the size of the brood does not seem to have any well-defined relation with the sex ratio in *Peromyscus*.

Separate calculations were made for the litters in which no deaths were recorded and for the litters in which deaths are known to have occurred. In the later data we find the sex ratio for incomplete broods, comprising 43 broods, to be  $83.64 \pm 11.26$ . For the 673 complete broods the sex ratio is  $118.09 \pm 3.38$ —the difference between incomplete and complete broods being  $34.45 \pm 11.76$ . While this difference is large enough to be of interest we cannot attach any great significance to it inasmuch as only 43 incomplete broods were considered. In the combined data we find sex ratios of  $91.45 \pm 4.76$  and  $104.65 \pm 1.79$  based

on 309 and 1,974 broods for the incomplete and complete broods respectively. Thus we do find a difference between the sex ratios of complete and incomplete broods but we do not feel justified in regarding it as significant in view of the meagre record of identified dead.

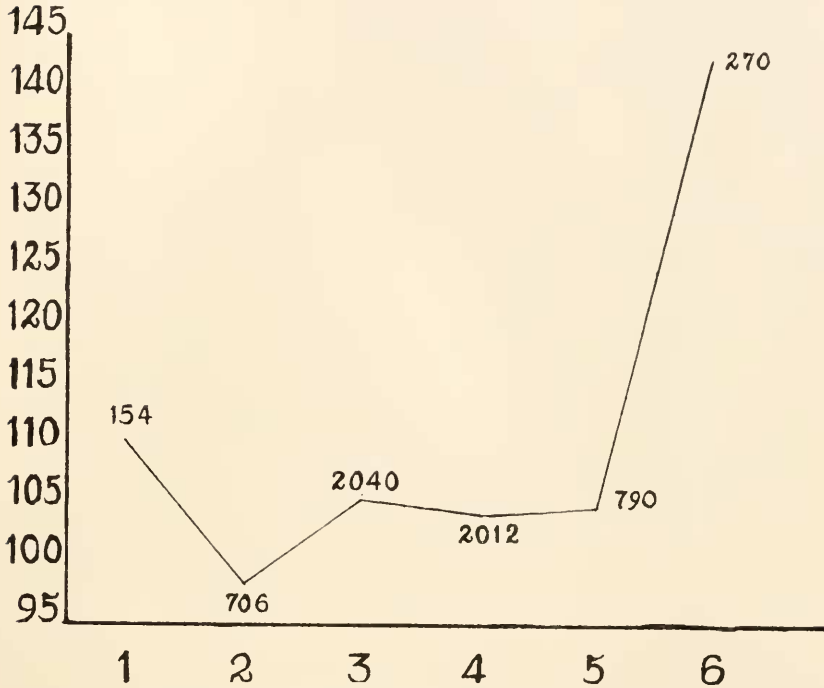


FIG. 3. Variations in the mean sex ratio, according to the size of the broods. Numbers along graphs indicate numbers of individuals.

#### *Combinations of the Sexes in Individual Broods.*

It is interesting to consider the possible tendency of members of a litter to agree with one another in respect to sex, that is, whether or not we encounter broods consisting entirely of the same sex more frequently than would result from chance. In the following table, using the combined data, we have arranged broods of each size in groups according to the number of each sex present. For example, broods of three present four possible combinations: 3 ♂, 2 ♂ + 1 ♀, 1 ♂ + 2 ♀, 3 ♀. The actual number of complete broods containing a given combination of males





and females and the "expected" number to the nearest integer are computed. Since the percentage of males in the combined data is 50.74, I have computed these last figures by expanding the binomial  $(1.015 + .985)^n$ . In the case of an equality ratio we should use the ordinary formula for probability, *e.g.*,  $(1 + 1)^n$ . Considering the comparatively small number of broods present in most of the groups we find a rather close agreement between the actual and the expected figures for all of the broods in which all members were of the same sex. The actual number of such homosexual litters, among broods containing from 2 to 6 individuals inclusive, was 409; while the most probable number on the assumption of purely random sex-production, was 422. If we consider fractions (a more exact procedure) this last figure becomes 420. In the earlier data alone a closer agreement than this was found, the figures being 276 and 274 for the actual and expected number of broods respectively. It would appear that the distribution of the sexes in single broods follows the laws of chance and there seems to be no tendency for fetuses (or germ cells) developing in the same parents at the same time to give rise to organisms of the same sex. We may likewise reiterate the conclusion of Sumner, McDaniel and Huestis, namely; "the non-occurrence of polyembryony or true twinning, at least with sufficient frequency to affect the results."

## RACE.

For the later data we have computed the sex ratio separately for the "pure" (non-hybrid) *polionotus* series and in the following table we have listed in addition the sex ratios for some of the other geographic races (subspecies) as computed by Sumner, McDaniel and Huestis.

Subspecies.	Males.	Females.	Ratio.
<i>polionotus</i> .....	120	89	134.83 ± 13.15
<i>gambeli</i> (La Jolla) .....	770	840	91.67 ± 3.07
<i>sonoriensis</i> .....	350	373	93.83 ± 4.70
<i>rubidus</i> .....	150	124	120.97 ± 9.91

The difference between "*polionotus*" and "*gambeli*" is  $43.16 \pm 13.50$  and may possibly be regarded as significant. But

we cannot say definitely that these figures imply the existence of any actual racial differences with regard to the sex ratio.

It is interesting to also observe here that in the subspecific hybrids of *Peromyscus polionotus* we find a sex ratio of  $114.61 \pm 5.79$  while the subspecific hybrids considered in the earlier report (mainly *P. maniculatus*) give a mean sex ratio of only  $104.76 \pm 3.41$ .

Parkes<sup>1</sup> briefly summarizes the data of many workers on specific variations in the sex ratio in man and other mammals.

#### HYBRIDIZATION.

In 235 broods comprising 735 individuals of  $F_1$  hybrids in the later series we find a sex ratio of  $114.61 \pm 5.79$ . While this is lower than the ratio for the pure "*polionotus*" stock (see p. 159), we cannot attach any significance to the latter figures since they are so small. For the same reason we do not feel justified in combining the later group with the earlier, in a comparison of pure and hybrid ratios. We may say, however, that in the earlier series alone the difference between the ratios for pure and hybrid stock was found to be  $11.49 \pm 4.1$ , the hybrid series giving the higher ratio. These results are in agreement with the conclusions reached by other workers, *c.g.*, Pearl (1908), King (1911), and Little (1919), that hybridization "per se" may result in raising the sex ratio.

#### THE YEAR.

The sex ratios and the number of individuals upon which they are based for the year 1922-1926 are as follows:

1922 (296) .....	106.34 $\pm$ 8.33
1923 (355) .....	106.43 $\pm$ 7.64
1924 (519) .....	120.80 $\pm$ 7.27
1925 (966) .....	113.93 $\pm$ 5.93
1926 (386) .....	125.60 $\pm$ 8.80

Although it is quite evident that there are no significant differences here it was thought worth while to present the figures in view of the fact that the earlier data on *Peromyscus* (1915-1921) showed such marked yearly variations. While these results were

<sup>1</sup> A. S. Parkes, "The Mammalian Sex Ratio," *Biol. Review*, Vol. II, No. 1, Nov., 1926.

inexplicable, they were statistically speaking, the most significant of all and the likelihood of obtaining one of the differences by "accident" was less than one in 40,000. It was further proven that these differences were "not due either to the seasonal distribution of births, to the preponderance of hybrid births in one year as compared with another, or to the operation of any of the other factors previously considered."

Inasmuch as it is evidently exceedingly difficult to correlate the annual variation in the sex ratio with any known influences, accurate data on the subject are generally lacking. Of course it is not impossible that the most "significant" figures may result from chance.

#### SUMMARY.

Data have been presented based upon 2,522 deer mice as recorded during the breeding experiments of Dr. Sumner, from 1922 to 1926. Earlier records (1915-1921) were added to the above and the combined data have also been presented.

The following results seem to be of most importance.

1. The mean size of 760 broods in the later records is 3.32. For the combined data comprising 2,321 broods the mean size is 3.25 mice per brood.

2. The sex ratio for the later data is  $114.93 \pm 3.19$ ; while that for the entire lot is  $103.01 \pm 1.64$ .

3. Considering the possibility of a seasonal cycle in the proportion of males and females born, we can only say that we find in the later data a maximum sex ratio in the August-September period followed by a minimum during October and November. In the combined data we find two annual maxima, one occurring in March and April, the other from August to October, and hence a fairly well marked biennial rhythm. Grouping the combined material according to 3-month periods we find in one arrangement that the biennial rhythm is practically eliminated while in another it is rather well marked. The existence of a seasonal cycle in the sex ratio of *Peromyscus* is not definitely proved.

4. The size of the brood in the combined material does not seem to have any well defined relation with the sex ratio in *Peromyscus*.

Although we find a difference between the sex ratio of complete

and incomplete broods we cannot regard it as significant in view of the meagre records of identified dead.

5. When the number of each possible combination of males and females, in broods of each size, is compared with the number expected according to chance, the conformity is found to be, on the whole, very close. For example, if we compare the actual and expected totals for all of the broods in which all members were of the same sex we find 409 as the actual number and 420, the "expected" number. Thus there is no preponderant tendency toward the production of homosexual litters and thus the non-occurrence of polyembryony or true twinning to any great extent.

6. While the sex ratio for the three subspecies of *polionotus* is "significantly" higher than that for other pure races of *Peromyscus* we cannot say definitely that these figures imply the existence of any actual racial differences with regard to the sex ratio in *Peromyscus*. The sex ratio of *polionotus* hybrids is likewise considerably higher than that of other *Peromyscus* hybrids which have been studied.

7. No significant yearly variations were found in the sex ratio of *Peromyscus* from 1922 to 1926.